The potential effects of climate change and sea-level rise are underestimated. . . . The potential direct effects of climate change and sea-level rise on the effectiveness of actions, including operations involving new water conveyance facilities, are not adequately considered. . . .

In their response to our preliminary draft review, the Department of Water Resources noted that “the scope of an EIR/EIS is to consider the effects of the project on the environment, and not the environment on the project”. If the effects of major environmental disruptions such as climate change, sea-level rise, levee breaches, floods, and the like are not considered, however, one must assume that the actions will have the stated outcomes. We believe this is dangerously unrealistic. CEQA requires impacts to be assessed “in order to provide decision makers enough information to make a reasoned choice about the project and its alternatives”.

Sea level rise is underestimated

- Independent Science Board estimated in 2007 that DWR could use estimates of 1 meter (3.25 feet) of sea level rise by 2100, but cautioned that melting of ice sheets could cause up to 2 meters (6.6 feet)
- NOAA 2012 guidelines – use high estimates of 2 meters for new infrastructure with a long expected lifetime
- Satellite observations show dramatic increase in rate of ice sheet melting
- DWR’s 2009 projections for water supply planning – 1.8 to 3.1 feet by 2100.
- BDCP sea level rise assumptions were based on this projection.
NASA: Antarctic ice sheet loss

Source: http://www.nasa.gov/images/content/416685main_20100108_Climate_1.jpg
Sea Level Rise – Cayan et. al.
California Climate Action Team

Figure 11. Past global mean sea level and future mean sea level based on global mean temperature projections (Ramsdorf 2007).

Source: BDCP DEIR/DEIS, Appendix 5A-D
Sea Level Rise – NOAA 2012

Source: NOAA Climate Program Office, Global Sea Level Rise Scenarios for the United States National Climate Assessment
Sea Level Rise – DWR 2009

Figure 12. DWR-generated future sea level rise projections based on 12 CAT scenario projections using Ramsdorff method (Chung et al 2009).

Source: BDCP DEIR/DEIS, Appendix 5A-D
Sea Level Rise – NOAA and USACE, Port Chicago (to 2035)

Source: Army Corps of Engineers online calculator
Projected changes in runoff

- California’s climate is unique

- Ensemble of global circulation models used for BDCP/WaterFix does well in Eastern North America and Europe, but a poor job in Western North America and California

- Still an active area of research

- Uncertainty of projections in future runoff needs to be addressed
Figure 20. Graphical depiction of the analytical process for incorporating climate change into water planning.

Source: BDCP DEIR/DEIS, Appendix 5A-D
Greenhouse gas emissions scenarios

- Climate model forcing requires assumptions about growth in greenhouse gas emissions
- BDCP/WaterFix models use the Intergovernmental Panel on Climate Change (IPCC) 2007 SRES greenhouse gas emissions scenarios
  - A2 – high -- some reduction in growth of emissions
  - B2 – large reduction in growth of emission
  - B1 – everybody drives a solar powered EV or rides a bicycle by 2060
Figure 15. IPCC SRES emission scenarios storylines and future global greenhouse gas emissions.

Source: BDCP DEIR/DEIS, Appendix 5A-D, p. 29
Climate Models
CMIP3 Database

General Circulation Models from climate research centers around the world

BDCP / WaterFix uses entire ensemble

California’s Climate Action Team used subset selected for representation of California’s climate

Source: BDCP DEIR/DEIS, Appendix 5A-D
Regional Bias in CMIP3 Models

Estimation of regional bias in precipitation (mm/day)
BLUE LINE – CMIP3 mean
BLACK LINES – Observed data
WNA is Western North America
ENA is Eastern North America
EUM is Europe and the Mediterranean

Figure 9.38 | Mean seasonal cycle of (a) temperature (°C) and (b) precipitation (mm day⁻¹). The average is taken over land areas within the indicated regions, and over the period 1980–1999. The red line is the average over all CMIP3 models; the blue line is the average over 22 CMIP3 models. The standard deviation of the respective data set is indicated with shading. The nearest-the-mean black line refers to the reanalysis and reanalysis data. Climate Research Unit (CRU) and ECMWF 40-year mean, (ERA-40) and ERA-Interim.
Regional Bias in CMIP3 Models


Closeup of Western North America (WNA)

(mm/day)

BLUE LINE – CMIP3 mean

BLACK LINES – Observed data
% Bias in annual precipitation

Colored x's are CMIP3

Green is 50% exceedance

Red is 95% exceedance
Regional Bias in Climate Models

Closeup of Western North America

% Bias in annual precipitation

Colored x's are CMIP3
Green is 50% exceedance
Orange is 75% exceedance
Red is 95% exceedance
Recommendations of Climate Change Technical Advisory Group (CCTAG)


Select climate models based on representation of historic hydrology in Western U.S. and California
2009 Climate Action Team – 6 GCMs

- Models selected for California by Cayan et. al.
- Shows significant drying for A2 emissions scenario, even in the near term

Source: BDCP DEIR/DEIS, Appendix 5A-D
Nonstationarity


- In water resources planning, it is often assumed that future hydrologic variability will be similar to historical variability, which is an assumption of a statistically stationary hydrology. This assumption no longer holds true under climate change where the hydrological variability is non-stationary. Recent scientific research indicates that future hydrologic patterns are likely to be significantly different from historical patterns, which is also described as an assumption of a statistically non-stationary hydrology. In an article in *Science*, Milly et al. (2008) stated that “Stationarity is dead” and that “finding a suitable successor is crucial for human adaptation to changing climate.”
Nonstationary runoff projections

- In *Water and Energy Sector Vulnerability to Climate Warming in the Sierra Nevada: Water Year Classification in Non-Stationary Climates* Null and Viers (2012)
- Used set of 6 GCMs selected for California by Cayan et. al.
- Did not map onto the historic 82 year sequence
- Showed dramatic increase in the frequency of dry and critically dry years by the end of the century
Null and Viers (2012)

Water and Energy Sector Vulnerability to Climate Warming in the Sierra Nevada: Water Year Classification in Non-Stationary Climates

Shifts in frequency of year types for the Sacramento Four River Index
Null and Viers (2012)

Water and Energy Sector Vulnerability to Climate Warming in the Sierra Nevada: Water Year Classification in Non-Stationary Climates

Shifts in frequency of year types for the San Joaquin Valley Index

Figure 7. SJR Relative Frequency Histograms for (a) 1951-2000, (b) 2001-2050, and (c) 2051-2099
BDCP method for dealing with uncertainty in climate projections

- Divide set of 112 projections into four quartiles
- Drier, less warming
- Drier, more warming
- Wetter, less warming
- Wetter, more warming
- Use quartiles to estimate uncertainty
Central Tendency Projection

- Clustered around mean change in precipitation and temperature

- Eliminates
  - 25% and less -- driest
  - 75% and more -- wettest
  - 25% and less warming
  - 75% and more warming

- Drier models were consistent with recent droughts in Southwest and California
Source: BDCP DEIR/DEIS, Appendix 5A-D
Central Tendency Projection

- Produces projections close to historical runoff patterns in the near term.

- Highest sensitivity (highest warming) models now appear most likely (Sherwood, *Spread in model climate sensitivity traced to atmospheric convective mixing*, Nature 2014.)

- These model projections were eliminated by 25%-75% pruning

- More warming generally means more drying
2010 Recommended Analysis for BDCP

- Do CALSIM runs for all quartiles (Q1-Q4) as well as Q5
- Sensitivity analyses only for highest sea level rise (1.4 m)

Source: BDCP DEIR/DEIS, Appendix 5A-D, p. 44
_recommendations_

- There is significant uncertainty about shifts in runoff due to climate change.
- Q2 drier, warmer scenario represents the greatest risk.
- Strongly agree with the 2010 recommendations to use the Q1-Q4 projections for input into all CALSIM runs.
- Needs to be explicitly considered in the CALSIM model results presented for the WaterFix Hearing.
Draft Biological Assessment

- ESA required assessment of Q1-Q4 alternative runoff scenarios
- CALSIM runs were produced for both the No Action Alternative and the Preferred Alternative
- The No Action Alternative is the same as the WaterFix Hearing No Action Alternative
- This analysis should have also been done for the WaterFix Hearing CALSIM model runs
Figure 5.A.A.3-12 Sacramento River at Freeport Monthly Flow for the NAA and PA under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

Source: Revised Draft BA, Appendix 5A
Figure 5.A.A.3-13 Sacramento River downstream of North Delta Diversion Monthly Flow for the NAA and PA under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

Source: Revised Draft BA, Appendix 5A
Figure 5.A.A.3-16 Monthly Delta Outflow for the NAA and PA under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

Source: Revised Draft BA, Appendix 5A
Paleoclimate and extreme droughts

- Khan et. al., *Climate Change Characterization and Analysis in California Water Resources Planning Studies, Department of Water Resources, 2010.*

- There is a lack of analysis of potential drought conditions that are more extreme than have been seen in our relatively short hydrologic record. There is significant evidence to suggest that California has historically been subject to very severe droughts and that climate change could result in droughts being more common, longer, or more severe. However, most current DWR approaches rely on an 82-year historical hydrologic record (1922–2003) on which GCM-generated future climate changed-hydrologic conditions are superposed. This record is likely too short to incorporate the possibility of a low frequency, but extreme, drought.
Tree Ring Reconstruction – Meko (2001)

Source: http://www.treeflow.info/content/sacramento-river-four-rivers-index-ca

...six-year droughts of the 1930s and 1980s-90s are as severe as any encountered in the tree-ring record. For longer running means the tree-ring record contains examples of drought severity and duration without analog since the start of the 20th century. For example, mean flow is reconstructed at 73 percent of normal (1906-2008 observed mean, 23.8x106 acre-feet) for the 25-year period ending in 1480.
Tree Ring Reconstruction -- Meko

Source: Meko, 2009 Extreme Precipitation Symposium, Exhibit IFR-1, p. 24
Tree ring reconstructions show that California has experienced many episodes of severe drought, as well as climate shifts.

There needs to be an explicit analysis of water supply and water quality for a repeat of the severe six year droughts of 1928-34 and 1987-1992.

Because of long periods of below normal runoff in the tree ring reconstructions, this is the minimum that should be considered.